Engineering Planning for Manufacture[1]

By G. A. PENNOCK

Synopsis: This article discusses the complete analysis, from a manufacturing point of view, to which every item of telephone apparatus is submitted at the Hawthorne Plant of the Western Electric Company. These works employing, at present, about 25,000, produce over 110,000 different kinds of parts which enter into some 13,000 separate forms of apparatus. The advantages of careful engineering analysis of each new job coming to the factory, as well as those which have been in production, are brought out. The various steps which are worked out in connection with each analysis are as follows: manufacturing drawings; the proper manufacturing operations and their sequence; the machines best adapted to carrying out these operations; determination of the kind of tools, gauges, weighing and other equipment; the determination of the probable hourly output for each operation; the grade and rate of pay for the operators; the kind and amount of raw material required; manufacturing layouts which tell the entire shop organization; each step in the production of the parts, and finally the best rate to be paid for each operation. In conclusion, the author discusses the personnel of the Planning Organization.

Introduction

THE essence of the successful operation of any industrial establishment is contained in the maxim "Plan your work—then work your plan." The first part of this maxim is by far the most important since the ability to work any plan depends fundamentally upon the excellence of the plan itself.

Farsighted planning, as applied to elementary factory operations, is a relatively simple problem. For example, the problem involved in planning the work of a foundry is to a great extent merely the the duplication of plans already standardized, but in a plant manufacturing widely diversified products, such as we have at Hawthorne, planning becomes at once more difficult and essential.

The General Manufacturing Department of the Western Electric Company provides the Bell System with telephone equipment which involves the production of over 13,000 separate and distinct forms of apparatus, in the construction of which there are used over 110,000 different kinds of parts made from 18,000 different kinds, sizes, and shapes of raw material. A number of these parts are produced in very small quantities.

The production of the varied product mentioned above involves not only all the usual wood and metal working operations, but also such lines of manufacture as: glass making, textile dyeing, manufacture of porcelain, electrolytic iron, vulcanized and phenolized fibre,

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soft and hard rubber in the form of sheet, rod, tube, and molded shapes, the insulation of wire with textiles, enamels, and paper, and the conversion of copper billets into wire.

These materials are used for making parts which, generally speaking, are quite small in size when compared with parts used in steam locomotives, gas engines, dynamos, and other kindred equipment common to the electrical and mechanical fields.

The fact that the parts are small in dimension, however, does not mean that the manufacturing difficulties are in proportion. On the contrary the problems involved in their manufacture are often times in an inverse ratio to the size of the part.

Fig. 1 shows a crank shaft about three feet long and the shaft used in the calling dial for machine switching about an inch and a half long. The layout of the operations required for machining the crank shaft is shown in the upper left hand corner. There are a total of eight.

Below at the left is shown the layout of operations for making the shaft for the dial. There are a total of eighteen.

As you will note from the data at the right, the number of machines involved is, roughly, the same in each case. These data illustrate the fact, however, that the small part may be more complicated and involve more engineering problems that the larger part.

Planning for the Future

As the manufacturing unit of the Bell System, the Western Electric Company in planning its production has had to bear in mind, first, that the facilities shall be adequate to turn out the tremendous volume of apparatus and equipment required from year to year; second, that the System's supply of equipment must be planned to eliminate, so far as is humanly possible, any interruptions; and third, that the System must get its equipment at the lowest possible cost.

Briefly, our program for providing buildings and equipment for the future is based on a five-year forecast of business made by each Associate Company and summarized by the American Telephone and Telegraph Company.

It takes approximately two years to erect and equip new buildings; consequently, capacity studies on floor space are made two years or more in advance and tool and machine equipment studies are made one year or more in advance, as this equipment can usually be provided in one year.

NOTE COMPARISON OF SIZE OF SHAFTS

SHAFT FOR NO. 2 TYPE CALLING DIAL

Oper's. Req'd. (18)

Rough form thread portion, and O. D. counterbore, finish turn, thread and cut off
Limits ±.0015″ for diam.
±.002″ for l'gth.

Rough and fin. form 2 diams, shear 1 diam., thd. and polish.
Limits +.000″,-.005″ l'gth.

Shear S. C. face to l'ght. burr and polish long end. +.000″
Limits —.001″ for diam.

Straddle mill flats—mill four (4) slots. (2) oper's. +.000″
Limits —.002″.

Machine and Tools

Davenport Auto Screw Machine, 5 chucks, 5 plain and form tools, 1 thread die and three gauges.

No. 1 B. & S. H. S. M.

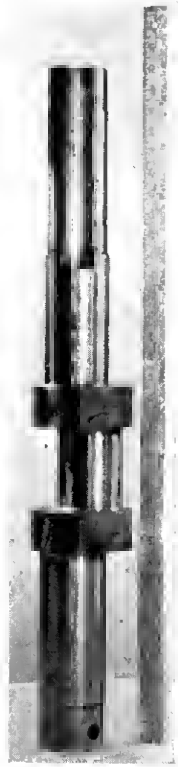
1 chuck, 2 form tools, thread die, emery stick and 4 gauges

No. 1 B. & S. H. S. M.

1 chuck, 2 form tools, emery stick and 5 gauges

Hand Mill

Milling fixture, vise and jaws and spec. cutters



CRANKSHAFT FOR NO. 21 BLISS PUNCH PRESS

Oper's. Req'd. (8)

Rough and finish, center, turn face complete and polish limits diam. +.008″,-.000″ length ±.008″. Mill concave keyways, ¾″ slot and 4 flats—3 oper's. Limits ±.005″. Drill ¾″ x ⅜″ hole.

Machines and Tools

Hendy 12″ x 5′ lathe, center drill, turning and polishing tools. No. 3 B. & S. mill machine milling fixtures, arbors and cutters. Cincinnati 1 sp. D:P. drill jig and drill

Fig. 1—Dial Shaft vs. Crank Shaft

The Advantages of Planning

In order to meet the requirements of the telephone business, the Engineering Departments of the System are constantly developing new designs and changing present designs with the object of improving the quality of, or reducing the cost of telephone service. This means that the products that we are manufacturing are constantly undergoing development, with the result that we are continually confronted with changing manufacturing problems.

The decisions reached by the various organizations of the Bell System to proceed with the introduction of the new and changed designs just referred to are based entirely on improved service, lower costs, or both; consequently, before any work on new developments can be done the Manufacturing Department must furnish firm estimates of the cost of one or any number of pieces of apparatus that may be required.

This is made possible by our ability to plan a job in detail on paper and to make an accurate appraisal of the manufacturing costs before production is started. The cost established, selling prices can be determined, and a final decision made by the System as to the merits of any new devlopment.

Furthermore, by scrutinizing the design and concentrating on the various manufacturing operations to be used before the tools are built, numerous changes can be introduced to facilitate manufacture and in this way avoid getting into the factory what have been termed " hospital jobs " which result in retarded production and inflated costs.

The two designs illustrated in Fig. 2 bring out what is possible in a manufacturing analysis of an engineering design. The part shown is the mounting plate used in the calling dial. The design originally showed ears, which were blanked out and turned over toward the inside of the blank and perforated, as shown in the upper view.

The lower view shows the design as it was developed due to the Manufacturing Department's suggestions to blank the ears from the inside of the blank and turn them outward, thus locating the mounting holes in exactly the same position as the engineering design, but saving material. It also simplified the bending of the ears. Instead of a double bend, there is an S bend. The holes were made larger also to permit perforating instead of drilling. The lugs and holes were also unevenly spaced so as to make it impossible to perforate or assemble the part in the wrong position. In shop language, the part was made "fool proof" in this respect, whereas the model was not.

It was formerly common practice among many manufacturers to leave the actual planning of the job to the shop foreman and to some extent this practice still exists. Obviously, under this plan, only the more commonly known methods will be employed as the shop man is not in a position to avail himself of the mass of engineering knowledge that has accumulated in connection with such work. We are convinced that the returns from engineering the actual manufacturing operations are as great as those realized from engineering the design of the product.

CALLING DIAL NUMBER
PLATE SUPPORT

Original Proposed Design
Objectionable features—lugs formed inward, requires large blank and a cam action tool or two operations in forming. Small holes do not permit perforating

Design Finally Adopted
Results of comments—lugs formed outward decreases the size of blank permits combined embossing and forming in simple tool. Holes increased in size

Fig. 2—A Modified Part

Factory Arrangement

Before describing our planning work more in detail, a few words should be said about our arrangement of machine equipment. Our metal working machine departments are laid out in such manner that the manufacturing operations are grouped into departments by class of work or operation and not by class of product. Each department performs some definite kind of operation, and each handles all the parts that require that particular operation. Thus we have punch press departments, screw machine departments, a milling department, a drilling department, etc.

The parts produced in these specialized departments pass in proper sequence through all the departments that have work to do on them and finally reach the assembly departments, where they are made up into finished units of apparatus.

The advantages of this method of dividing manufacturing work are that it minimizes investment by avoiding duplication, increases machine activity, provides greater flexibility of equipment, and permits the training of unskilled labor to the point of full productivity in the shortest time.

The conclusion may have been reached that departmental groupings by classes of machines such as have been described is all right for a business of little variety, but that in such a large endeavor handling so diversified a product, it would seem nearly impossible to maintain a proper balance of equipment in all the departments.

As a matter of fact, adjustments are frequently made due to increased or decreased demands, and we frequently have to step up or down both our rate of production and our capacity for certain lines of products or certain definite articles.

To meet this situation, we have capacity data giving the number of hours required by machine operations, assembly operations, etc., for one thousand pieces of each kind of apparatus. With this information, we can readily compute the increase or decrease in shop equipment due to changes in schedules.

There are, of course, some departures from this general practice of functionalizing our machine departments in the case of certain products that require a large amount of special machinery. In these cases, the few "general use" type machines required are grouped with the special machinery into a department for the complete manufacture of the article.

This special practice is also carried out in connection with the manufacture of certain piece parts. These cases are confined to a

few parts manufactured in large quantities where it is found expedient to group a variety of machines in order to reduce the amount of handling to a minimum. An example of this is the manufacture of the top part of the desk stand which supports the transmitter, which we know as the "lug holder." This part is made from brass tubing. The operations involved in making the part are, cut to length, burr, several swaging operations, and a number of punch press operations, such as perforating, embossing, and trimming. We have in this case grouped together in the proper sequence the required number and sizes of milling, burring, swaging and hammering machines and punch presses.

Jobbing Shop

We also have a group of departments known collectively as the "Jobbing Shop" which is equipped to perform all the usual machining operations. These departments handle the manufacture of special apparatus, which is made in such small quantities that it does not pay to make the elaborate manufacturing preparations which are justifiable in the case of heavy running apparatus for which there is an established demand.

To give you some picture of just what we set out to do when we plan a job, the following different steps or problems which must be worked out are enumerated briefly:

1st. Manufacturing Drawings.
These drawings tell the shop in detail what is to be made and what the requirements are.

2nd. Manufacturing Operations.
The actual operations required to produce the parts and their proper sequence are decided upon.

3rd. The machines on which the operations are to be performed are determined.

4th. The kind of tools, fixtures, gauges, conveying, and other equipment to be used is determined.

5th. An expected hourly output for each operation is set up.

6th. The grade and rate of pay of the operators to be employed are determined.

7th. The kind and amount of raw material required per thousand parts and the form in which it shall be purchased are determined.

8th. Manufacturing Layouts.
These layouts tell the entire shop organization each step in making the parts shown on the manufacturing drawings.

9th. The piece rate to be paid for each operation is determined after actual manufacture is started.

Manufacturing Drawings

The manufacturing drawings prepared for any piece of Western Electric apparatus comprise complete detail drawings for each part, an assembly drawing showing how the various parts are associated, a stock list of the parts required and the quantities of each, and a test sheet which shows the mechanical and electrical requirements which the apparatus must meet in order to insure satisfactory performance in the System.

In the preparation of these drawings, standards are followed which insure that the designs as far as possible will permit of rugged tool construction which will insure long tool life; that the holes are of such dimensions as will permit them to be perforated wherever possible; that thread sizes for the tapped holes selected are such as to insure minimum tap breakage; and other similar details.

Manufacturing Operations

Before deciding upon the manufacturing operations for any part, a careful detailed analysis is made by the Planning Engineers to determine just what operations are required and how the operations shall be performed in order to obtain a satisfactory production in the most economical way.

In the case of simple parts, it is not a difficult task to determine the manufacturing operations required and their proper sequence. A large proportion of the parts, however, is in the fairly difficult class, and the ingenuity of the Planning Engineer is called upon, together with the advice and guidance of his superiors, in determining the manufacturing operations to be used in these cases.

A fair proportion of our product makes up what might be called the "difficult class" of parts to manufacture, and in setting up the proper procedure in these cases, we frequently hold conferences where the best talent along the particular lines under consideration is called into consultation in determining the best procedure. In many of these cases actual experimentation is carried on before the final tool line-up is decided upon.

Machine Equipment

The machine equipment on which the operations are to be performed is the next thing given consideration, and the most important features are:

1st. To select a machine that is capable of producing the parts to the desired accuracy.

2nd. To select a machine that will result in the maximum production, keeping in mind, of course, the accuracy required.

3rd. To give proper consideration to the investment, maintenance and overhead charges incurred by the machine selected so that these charges do not offset production economies expected.

4th. To insure that the machine selected is up to date with regard to the latest machine practice developments worked out by Hawthorne and by commercial machine manufacturers.

There are, of course, many other features which must be taken into account in selecting the machines for the manufacture of various kinds of parts.

In the case of blanking operation on a punch press, the object is to secure the smallest and therefore the fastest press which has sufficient tonnage capacity to perform the operation required.

Where the part is to be manufactured on an automatic screw machine, the problem is to select the fastest machine that will produce the work to the accuracy required, and at the same time select a machine that has a sufficient number of spindles and tool positions to permit all the operations required being performed before the parts are finally cut from the rod.

A part having a large number of holes to be drilled will necessitate the selection of a multiple spindle machine that can be set up to produce the maximum number of holes in one or several parts at each operation of the drill press.

We have worked out numerous improvements in commercial machinery that have now been incorporated in the product of many machine tool manufacturers. Some of the most important of these are motor driven punch presses, screw machines, milling machines, lathes, etc.

Fig. 3 shows the old belt-driven milling machine. It does not give you a true picture of the whole job, since the overhead drive which is the most objectionable feature does not show in the picture.

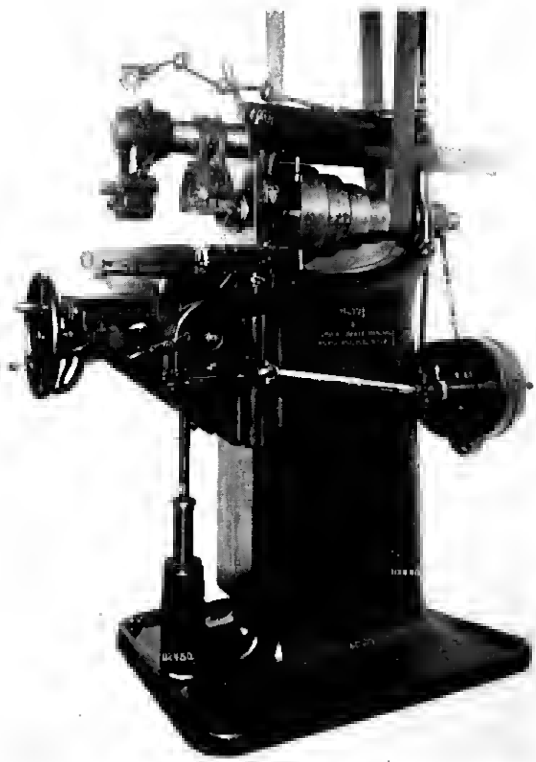


Fig. 3—Belt Driven Milling Machine

Fig. 4 shows the modern motor-driven milling machine with the motor mounted in the base and a chain drive enclosed in the housing at the back driving the spindle.

At our suggestion, several of the largest manufacturers of screw machines have incorporated screw slotting devices as standard equipment for multiple spindle machines.

We have just recently worked out a design whereby a high speed screw machine, formerly adapted to brass parts only, can now have its spindle speed reduced through change gears so as to make it adaptable for iron and nickel silver parts, thus providing greater flexibility.

Punch presses were formerly liable to serious damage if two blanks were accidentally placed in a forming die. We have worked out a design of ram which contains a "shear ring." This consists of a soft metal ring so incorporated in the connecting rod of the press as to

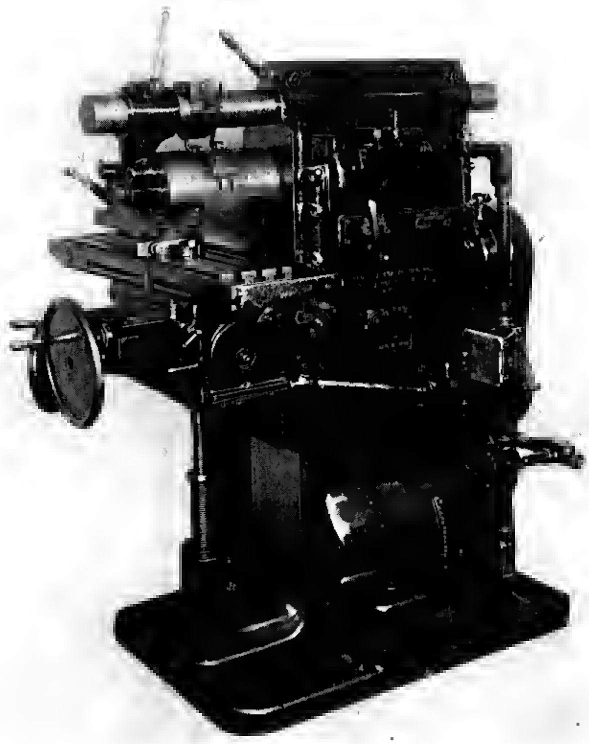


Fig. 4—Motor Driven Milling Machine

shear at any predetermined pressure, thus allowing the connecting rod to telescope instead of breaking the die or frame of the press. This improvement permits operating punch presses safely at greater speeds than are usual on this type of equipment.

Numerous other similar improvements have been worked out, many of which have been patented.

Tools

The annual demand for the product is the most important factor in determining the kind of tool, fixture, and gauge equipment to be provided.

Our most intricate engineering problems arise in connection with punch press tools as there is almost no limit to the variety of operations that can be performed on this type of machine.

If the demand for a part made on a punch press is small, it is often found more economical to build simple tools which will blank out, perforate and form in separate operations, rather than to build more elaborate tools at a higher cost which will combine two or more operations into one.

The effect of quantity on the design of tools may best be shown by a concrete case.

THE EFFECT OF ANNUAL DEMAND ON CHOICE OF MANUFACTURING METHOD

Yearly Req.	Material	Type of Machine	Type of Tool	Tool Cost	Cost per M	Tool Cost per M Parts	Saving per Year
5,000	5/8″ Brass Rod	Hand Screw Machine	General use Tools	....	$10.00	......	....
30,000	1/15″ Sheet	Punch Press	1 at a time Tandem Perforating and Blanking	$150.00	2.30	$5.00	$231.00
500,000	" "	" "	3 at a time Tandem Perforating Perforating and Blanking	400.00	1.72	.80	290.00
3,000,000	" "	" "	7 at a time Tandem Perforating and Blanking	600.00	1.52	.20	600.00

Fig. 5

Take, for illustration, the case of a simple brass washer 5/8″ in diameter, 1/16″ thick and having a 1/4″ hole. As shown in Fig. 5, with a requirement of 5,000 a year, the washer would be made from rod stock in a hand screw machine using general use tools at a cost of $10.00 a thousand; for 30,000 a year it would be made from sheet stock in a punch press using a one-at-a-time tool, at a cost of $2.30 a thousand; for 500,000 a year a three-at-a-time tool would be used at a cost of $1.72 a thousand; for 3,000,000 a year a seven-at-a-time tool would be used at a cost of $1.52 a thousand.

In each one of these steps, as shown in the columns at the right, the additional tool investment, necessitated by the more advanced

method, would be liquidated in one year by the decreased manufacturing cost.

Where a high degree of accuracy is required on a piece of apparatus, the overall effect on the tool equipment is to require a greater number of individual tools, as well as to require tools of a higher grade of workmanship. For instance, it may be necessary in the case of a punch press part to hold certain dimensions of the blank to extremely close limits, and this quite often requires an additional operation of shaving the blank to size. This adds an additional tool to the equipment, as well as requiring a tool of greater accuracy.

You will appreciate that the matter of interchangeability is one of great importance—first, because the parts must go together in the assembly departments without any further fitting—and second, the parts and pieces of apparatus shipped over the entire country for repairs and maintenance must be exact duplicates of the old.

It costs more to make interchangeable parts than to make inaccurate ones that are not always interchangeable, and the Planning Engineer can control the tool and manufacturing costs very largely by his judgment in the selection of limits.

Hourly Output

The Planning Engineer, in analyzing the work on a given part for the operations, machines and tools to be provided, from his experience and training in the particular kind of work he is handling, is able to establish an expected hourly production for each operation he handles. He is, of course, guided in this by his experience on similar parts and by the speed of the machines selected for the operation.

The setting up of the expected output for assembling operations is more difficult, but here also the special training and experience of the engineer along that line of assembly work enable him to set up an expected output which is approximately accurate. In some cases, we go so far as to tear down and reassemble models of the apparatus in order to obtain the necessary data.

The output per hour on each operation enables the engineer to compute the number of each kind of tool, including spares which must be built, to produce the required quantity of each part. The number of tools required is obviously dependent on the speed of the operation, and here again you see the effect on tool costs if the engineer fails to select the fastest machine suitable. When it is considered that we have nearly $3,000,000 invested in tools for the manufacture of panel machine switching apparatus alone, it can be appreciated what planning means to us.

Labor Grade

The Planning Engineer, in addition to establishing the values already mentioned, has also the responsibility of selecting the grade of labor which is to be used in performing the various operations. Different grades have been established for men and women, and each grade covers a sufficiently broad range of rates to enable us to hire the employees at the starting rate of the grade and to advance them in the grade as they become more proficient and experienced.

Raw Material

The Planning Engineer specifies the kind and amount of raw material required for each part including the scrap allowance. He also specifies the form in which it shall be purchased—that is to say, whether in rod, tubing, and in the case of sheet stock whether in the shape of sheets, strips, or rolls.

Manufacturing Layouts

The next step in preparing a piece of apparatus for manufacture is the working up of detailed manufacturing layouts. These layouts constitute the "sailing orders" for the shop, covering each operation to be performed, how the work is to be done, the sequence of the operations, the tools and machinery to be used, raw material and quantity required, and the stock room to which the parts shall be delivered upon completion.

These layouts are got out in the form of duplicated sheets and a complete layout for each part is sent to every department having work to perform.

Piece Rates

When all the preparation steps have been completed and after the various operations have been tried out and are running in the operating departments on a satisfactory commercial basis, the Planning Organization proceeds to establish piece rates on each operation.

The piece rates are established by the same organization of engineers who plan the work, and the responsibility of seeing that the estimated outputs are realized devolves upon this organization. Before proceeding with the studies involved in establishing the piece rate, the Planning Engineer checks back against the original planning data and the manufacturing layout, and, in this way, ascertains the method

as originally laid out, together with the expected outputs. His task then becomes one of seeing that the expected output or better is attained.

This, in many cases, involves a very detailed time and motion study of the elementary operations necessary to complete the job in order that it be brought to a high state of efficiency. In cases where the expected output cannot be realized by the original method, other methods are worked out wherever possible to bring about the desired result.

Just a word right here on our piece rate policy: when piece work was introduced many years ago, the policy was established that after a rate had been once issued it should not be cut unless a change had been made in the method of manufacture. In other words, we take the stand that an issued rate is a contract which cannot be revoked so long as the operation is done in the same manner as covered by the piece rate card.

To satisfactorily carry out a policy of this kind, it is obvious that our piece rate setting must be something more than mere stop watch observation. In order that piece rates are established which are accurate and fair to both the employee and the Company, it is necessary that the engineers setting the rates be well versed in the class of work being rated, and have a thorough knowledge of the amount of work which can be consistently produced by the operators.

Our experience with the straight piece work form of incentive has been very gratifying, and in our opinion this is very largely due to the following three reasons:

1st. Our policy of not cutting rates.

2nd. Our practice of making careful time studies in setting our our rates.

3rd. Our guaranteeing the employee's day rate regardless of his earnings on the piece rate.

The work of the Planning Engineer is not completed, however, upon the establishment of the piece rate, since it still rests with him to clear any difficulties the shop may experience due to any shortcomings of any of the planning work.

If the raw material provided will not satisfactorily produce the parts, he is called upon either to add operations or to specify other material; if the tools will not produce the parts to the required accuracy, or at the required rate, he is called upon to have satisfactory changes made to the tools or to provide new equipment.

In case the operators are unable to produce sufficient parts to make satisfactory piece work earnings after a reasonable trial, the Planning Engineer is called upon to either demonstrate that satisfactory earnings can be made, or to increase the rate.

The Planning Engineer is also called upon to assist in overcoming manufacturing difficulties for which he is not directly responsible, and a special unit has been set up to assist the shop in cases of this kind when difficulties are encountered.

From this, it can be seen that the Planning Engineer has not only the responsibility of planning the work, but he is also charged with seeing to it that the plan works out.

Cost Reduction Work

There is still one more highly important function performed by our Planning Organization, viz., Cost Reduction Work.

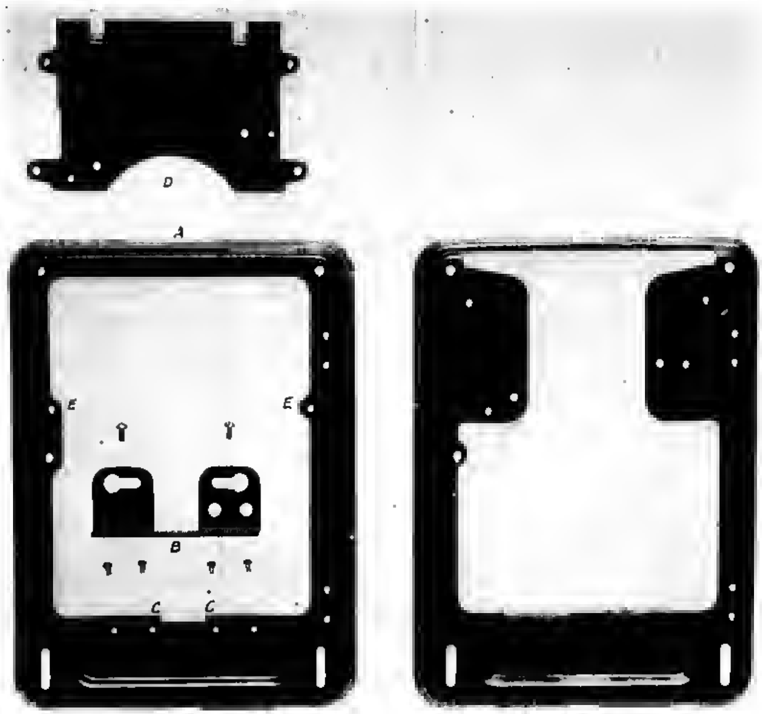
It might appear that after the careful thought already given to the methods to be employed in producing a piece of apparatus, the necessity for further study has been eliminated. This, however, is not the case, since in the original planning we must adhere closely to methods and processes that have been proved in, in order that the products may be produced on a specified date and at a predetermined cost.

In other words, we cannot take any short cuts at this stage of the work that we are not sure will work out successfully. However, after the piece of apparatus is in production, we are in a position to review the case and try out new ideas, improved methods, tools and machinery, without jeopardizing production. Naturally, any improvements worked out successfully by the Cost Reduction Engineers are later used by the regular Planning Organization when applicable on future work.

This cost reduction work is handled on a strictly business basis, i.e., the cost of the case is charged up against the savings effected and our records show that the returns on this work are very high.

There is a typical illustration of a cost reduction case shown in Fig. 6. This is the base for the sub set housing on which the apparatus is mounted. The old design is shown at the left. There were three separate pieces which had to be assembled together. Part B was riveted to the base *A* at *c*, *c* to form the ears which stand at right angles to the base. Part D was assembled to the base *A* with two machine screws, *E*, *E*. The design was changed at the suggestion of

the manufacturing department to make the part in one piece. It had previously been thought too complicated to combine all these operations in one part, but the tools were successfully developed, and the saving on this particular job amounted to something like one hundred thousand dollars a year, or about ten cents a piece.



ORIGINAL DESIGN
Consists of three individual parts, requires assembly with rivets and screws

ADOPTED DESIGN
One piece construction. Same No. of operations required to make as body of old design. No brackets required.

Fig. 6—Sub Set Base

The Personnel

So far the job we have to do and how we do it has only been dealt with, and the qualifications and training of the personnel required have not been mentioned.

Our Planning Organization is laid out in a manner similar to our shop departments; that is, the planning of the various manufacturing

operations is divided into class of work or operations and not by class of product, each class being handled by a group of planning engineers in charge of an expert thoroughly familiar with the line of manufacture he handles. In this manner each group performs some different line of planning and handles all the various parts that require that particular operation.

The personnel of our Planning Organization, exclusive of department supervisors and clerks, consists of 86 college graduates, 168 trained men who have come to this organization from our shop departments, or who have had experience in other shops, and 38 men who are neither college graduates nor shop men. The last group of men are mostly those of high school education who have been trained in our line of work.

The requirements of the Planning Engineer on whom the responsibility rests for the successful manufacture of our apparatus are quite extensive. He must first have the ability to plan the manufacture of the apparatus in the most economical manner consistent with the quantity and quality desired and this, of course, cannot successfully be done without a thorough knowledge of the methods and practices necessary in carrying on manufacturing activities along one or more definite lines. He must have a large measure of foresight, thereby reducing to a minimum the difficulties that are bound to occur when the manufacture of a new or changed piece of apparatus is started.

Furthermore, he must make a study of the design of the apparatus under consideration to determine if there are features of it which present manufacturing difficulties either from a tool, assembly, or adjustment standpoint. This part of our work involves a discussion of the manufacturing problems on a new design with the Engineering Organization and the men who handle this work must be able to express themselves in a clear and concise manner to insure that proper consideration is given to the manufacturing suggestions.

It goes without saying that the men who fit best into this organization are those who have had the benefit of an engineering education, preferably specializing on manufacturing methods.

We have, as you will have noted, a large number of planning engineers who have had actual shop experience either with us or in other manufacturing plants, and little or no technical education before working in the shops.

It is noticeable that these men, almost without exception, have realized their handicap due to the lack of a technical education and have either taken advantage of our schools or school work outside.

As stated previously, we have three main sources of supply for the men making up our Planning Organization; first, the Engineering Institutions; second, shop men who have the experience and have to some degree educated themselves in engineering; and third, high school graduates whom we have trained.

Such a combination of trained men makes a strong organization in which the man of superior education and the practical man are mutually helpful to each other in the successful working out of our manufacturing problems.